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Titre du document / Document title
Development of spin-on dielectric (Silk<[TM]>) etch process for 0.13μm Cu-low K interconnects technology

Auteur(s) / Author(s)
RAMANA MURTHY B. (1) ; CHEN Y. W. (1) ; CHEN X. T. (1) ; Mathad G.S. ; Rathore H.S. ; Konda K. ; Reidsema-Simpson C. ;

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Electrochemical Society, Electronics Division, Pennington NJ, ETATS-UNIS

Résumé / Abstract
This paper deals with the development of reactive ion etching (RIE) process of low-k organic polymer spin-on dielectric (SOD) material, SiLK<[TM]> (Trade mark of Dow Chemical, USA), for 0.13 pm Cu-low k interconnects technology. The etch process was developed in dipole ring magnet (DRM) etcher using dual hard mask CVD layers and trench first integration scheme. The process was evaluated for metal 1 trench, via, dual damascene trench etching and final copper cap removal. Further, etch process was evaluated for SiLK stack with SiN or SiC as hard mask, etch stop and copper cap layers. Some challenges in etching different structures which are important for device yield were also discussed based on electrical test data. The etch process consistency was clearly seen through the successful integration of multi metal layers in SiLK for 0.13 μm technology node.

Revue / Journal Title
Proceedings - Electrochemical Society (Proc., Electrochem. Soc.) **ISSN** 0161-6374

Source / Source
Congrès
Copper interconnects, new contact metallurgies/structures, and low-k interlevel dielectrics II (Orlando FL, 12-17 October 2003)
Copper interconnects, new contact metallurgies/structures, and low-k interlevel dielectrics N°2, Orlando FL , ETATS-UNIS (12/10/2003)
200319, vol. 10, pp. 195-203, [Note(s) : IX, 276 p.] (6 ref.) **ISBN** 1-56677-390-3 ; **Illustration** : Illustration ;

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Mots-clés français / French Keywords
Multicouche ; Revêtement ; Polymère organique ; Diélectrique basse permittivité ; Fabrication microélectronique ; Circuit intégré ; Essai électrique ; Damasquinage ; Polissage mécanochimique ; Technologie tranchée ; Dépôt chimique phase vapeur ; Dipôle ; Gravure ionique réactive ; Interconnexion ;

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Mots-clés espagnols / Spanish Keywords
Capa múltiple ; Revestimiento ; Dieléctrico baja constante dieléctrica ; Fabricación microeléctrica ; Circuito integrado ; Ensayo eléctrico ; Damasquinado ; Tecnología trinchera ; Depósito químico fase vapor ; Dipolo ; Grabado iónico reactivo ; Interconexión ;

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Development of Slurries for Polishing SiLK™-Integrated Wafers

Dr. David Merricks

IITC 2003

Acknowledgements to Bob Her, David Tysiac, Sheldon Mao, Lynn Murray of Ferro Electronic Material Systems and Ketan Itchaporia, Michael Simmonds of Dow Chemical

Outline

- **Introduction to SiLK™ Integrated Wafers**
- **Polishing Approaches**

- **Polishing Studies**
  - **Material Selectivities and Removal Rates**
  - **Polishing - Stopping on SiLK$_{TM}$**
  - **Polishing - Stopping on SiCN**
  - **CMP-Stop Evaluation**
  - **Planarization Efficiency**
- **Ferro Slurries**
  - **Tizox SRS-908 Copper Slurry**
  - **Tizox SRS-876 Damascene Slurry**
- **Future Work**

SiLK$_{TM}$-Integrated Wafers

Top hardmask (200nm SiO2)

Lower hardmask SiCN 100nm

Dielectric (520nm SiLK)

Copper (1um EP Cu + 100nm seed)

Barrier layer (25nm Ta)

Si wafer (high conductivity)

CMP-1 Wafers

Top hardmask (0-100nm SiO2)

Lower hardmask (100nm SiCN)

Dielectric (520nm SiLK)

Copper (1um electroplated + 100nm seed)

Barrier layer (25nm Ta)

Si wafer

Isolation layer (550nm SiO2)

Copper diffusion passivation layer (50nm SiCN)

CMP-2 Wafers

Objective - develop slurries and polishing processes compatible with

the materials used in SiLK$_{TM}$/Ensemble integrated stacks

Ensemble Spin-on Stack

2-Slurry Polishing

Process

Cu/Ta/TEOS/SiCN/SiLK/Si

1st step

2nd step

or

- **The initial development work was carried out on a Strasbaugh 6EC**
- **rotary tool. CMP-1 and CMP-2 wafers were polished on the Applied**
- **Materials Mirra tool**
- **IC1000/Suba IV pads were used throughout**

SiCN/SiLK/Si

SiLK/Si

- **A 2-slurry polishing scheme is favored, to minimize dishing/erosion**

Material Selectivities

- **Slurries have been developed which give both**

low- and

high-selectivity across the various materials found in the CMP-1

and CMP-2 integrated stack. Examples are shown below.

- **Copper slurry removal rates;**

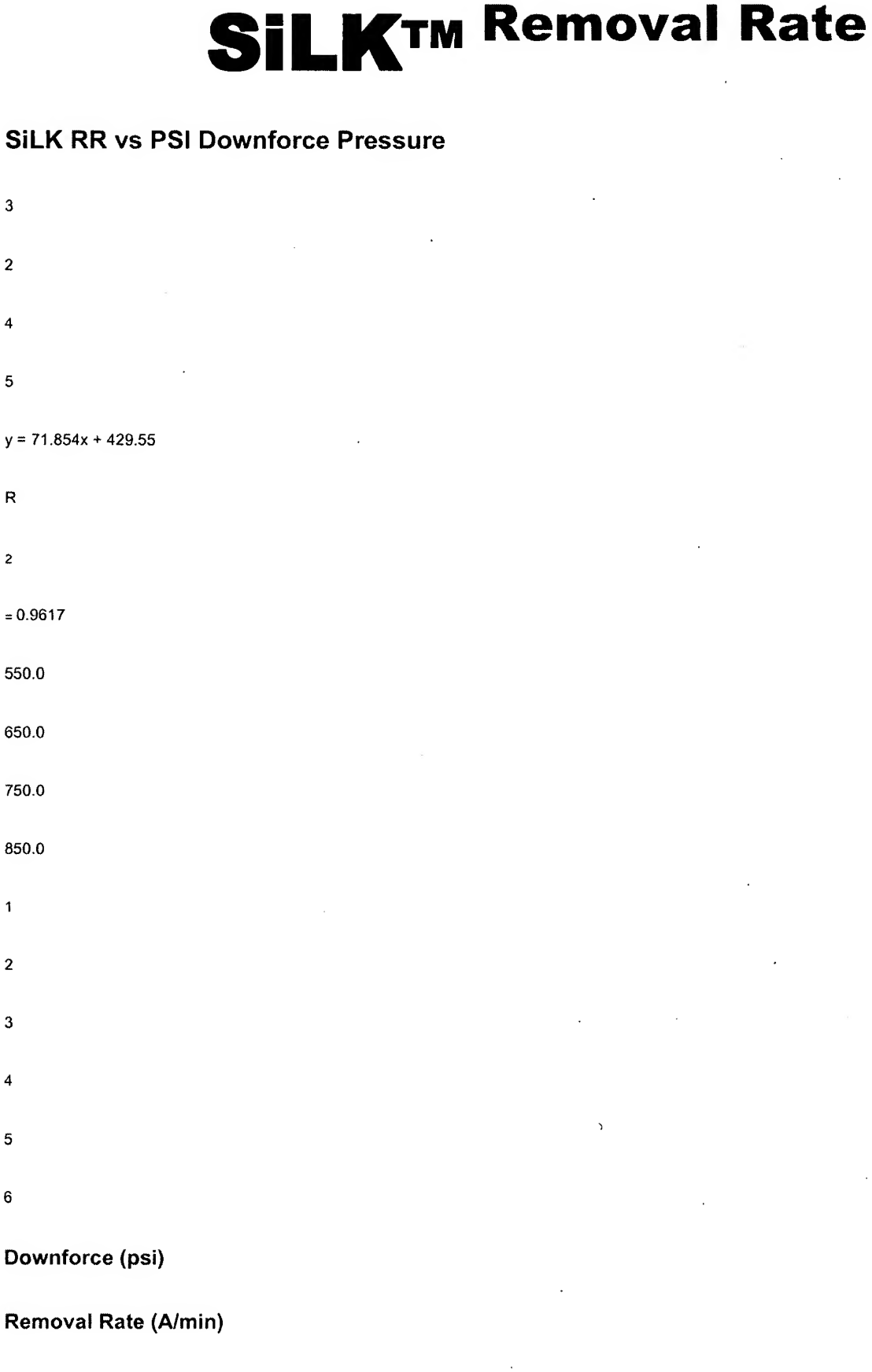
	Cu	Cu %WIWNU	Ta	TaN
Slurry IA	5500-6500	3-5	<50	<50
Slurry IB	5000-6000	3-5	195	262

- **Damascene slurry removal rates**

	Cu	Ta	TaN	TEOS	SiLK™
Slurry IIA	570(1)	711(1.25)	689(1.21)	917(1.61)	569(1)
Slurry IIIA	147(1)	519(3.53)	753(5.12)	56(0.38)	---

- **Rms surface roughness of post-polished $SiLK_{TM}$ is typically <3 Angstroms**
- **and %WIWNU is <3%.**

SiLK™ Removal Rate



- Slurry used here is IIA
- Strasbaugh 6EC polishing tool

Polishing - Stopping on SiLK™

- Slurries have been developed for direct polishing on SiLK$_{TM}$.
- FTIR spectroscopic analysis carried out at Dow, Midland has shown that these slurries do not lead to any oxidation of the dielectric surface and therefore no change in dielectric constant
- A modified edge lift-off (m-ELT) technique has shown there is
- no delamination or peeling of SiLK$_{TM}$ under the processing downforces used (2-3psi)

- In low-selectivity schemes, the SiLK$_{TM}$ RR should closely match
- the RRs of copper and barrier

	Cu	Ta	TaN	TEOS	SiLK™
Slurry IIA	570(1)	711(1.25)	689(1.21)	917(1.61)	569(1)
Slurry IIB	818(1)	755(0.92)	892(1.09)	850(1.04)	813(0.99)
Slurry IIC	361(1)	684(1.89)	888(2.45)	903(2.5)	868(2.4)

Polishing - Stopping on SiLK™

- The selectivities are easily 'tunable' by the choice of additives
- Damascene slurries have been developed that lead to a very low
- RR for SiLK™ (polishing can stop on SiLK™);

	Cu	Ta	TaN	TEOS	SiLK™
Slurry IID	500(1)	780(1.56)	861(1.72)	755(1.51)	<50

- ....or give a very high SiLK™ RR relative to other materials in
- the stack;

	Cu	Ta	TaN	TEOS	SiN	SiLK™
Slurry IIE	133(1)	97(0.73)	258(1.94)	204(1.53)	152(1.14)	2903(21.82)

- RRs are in A/min, polished at 3psi/60rpm/200ml-min flow rate

Polishing - Stopping on SiCN

- Ideally, the CMP consumables should never come into contact with
- the SiLK™ material
- Hardmask materials are integrated to protect the soft low-modulus
- materials during CMP
- SiCN (k=4.9) is used as CMP-stop in CMP-1 and CMP-2 wafers
- However, using many slurries (i.e. slurry IIA) the RR of SiCN is high
- A new slurry (IIIA) was developed which gives very low SiCN

removal

- This slurry has been used along with the copper slurry IB in a 2-slurry
- polishing scheme for CMP-1 wafers, stopping on SiCN
- Removal rates (A/min) for IIA and IIIA are shown below (2psi/60rpm);

	SiCN	TEOS
Slurry IIA	69	2365
Slurry IIIA	956	602

- Work continues on evaluating additives for further selectivity optimization

Polishing - Stopping on SiCN 2

- Polishing on the AMAT Mirra tool has shown that it is possible to

- use a non-selective Damascene slurry with CMP-1 wafers and stop
- on SiCN using optical endpoint detection
- The trace for slurries IB and IIA is shown below;

CMP-Stop Comparison

Slurry IIA

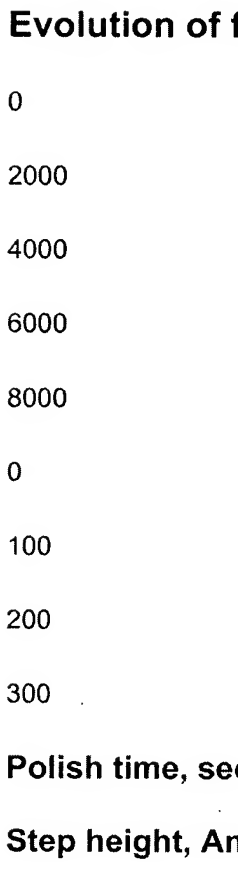
Slurry IVA

Slurry IIIA

- Several slurries have been evaluated with alternative CMP-stop materials
- such as SiC and Ensemble CS (organosilicate, k=2.9)
- SiC and SiCN showed similar polishing characteristics, but Ensemble CS
- gave relatively high RRs from all slurries - more work is necessary

CMP-2 - Planarization

- A 2-slurry process was used to measure step-height reduction
- across a CMP-2 wafer (in this case on 90% dense features)
- Here, the second slurry was introduced after 80 seconds



Ferro Slurries for Cu/Low-k Polishing

Copper Slurry: Tizox SRS-908

- Formulated to remove the bulk of the copper overplate
- RR of copper in the 5000-6500 A/min range using
- moderate to low range of downforce pressures and
- platen speeds
- Very low defectivity/pitting observed
- RMS surface roughness - 10-15 Angstroms
- Long shelf (oxidizer is separated)
- Effective with downforce pressures compatible with
- low-k dielectric integration

Ferro Slurries for Cu/Low-

k Polishing

Damascene Slurry: Tizox SRS-876

- Formulated to remove residual copper and barrier layer
- Close match of Cu/Ta/TaN/TEOS/SiLK™ RRs
- RRs/selectivity (at 3psi/60rpm) for
- Cu:Ta:TaN:TEOS:SiLK$_{TM}$;
- 818(1):755(0.92):892(1.09):850(1.04):813(0.99)
- RRs can be tuned in the 500-900 A/min range
- Selectivities can be tuned by choice of additives
- No copper pitting or corrosion
- Effective with low and moderate downforce processes
- compatible
- with low-k dielectric integration - no adhesion failure
- Slurries are compatible with SiLK$_{TM}$ low-k dielectric
- materials
- - no change in dielectric constant

Future Work

- A link to the Ferro SiLKnet work can be found on the SiLKnet
- website and also on;
- www.ferro.com/ourproducts/electronic/knowle

- A new cleanroom facility (5000 sq.ft - 2500 sq.ft of class 10 area)
- at FEMS Penn Yan, NY has been qualified and is scheduled to be
- operational by the end of June
- Future SiLKnet work will be carried out in this facility on the
- Applied Materials Mirra tool
- Slurries and processes for polishing CMP-1 and CMP-2 wafers
- containing porous SiLK™ (and SiLK-D when available)
- will be developed
- Both high- and low- selectivity slurry formulations will continue
- to be developed

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	22	"silk (TM)"	USPAT; EPO; DERWENT	AND	ON	2007/04/05 17:18
L2	15	1 and dow chemical	USPAT; EPO; DERWENT	AND	ON	2007/04/05 17:18